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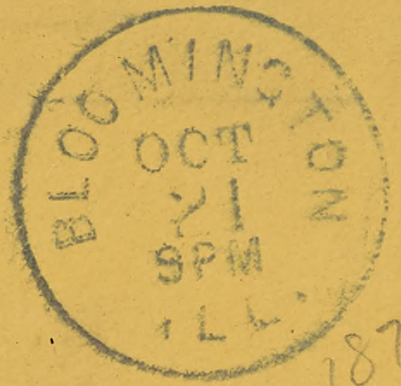

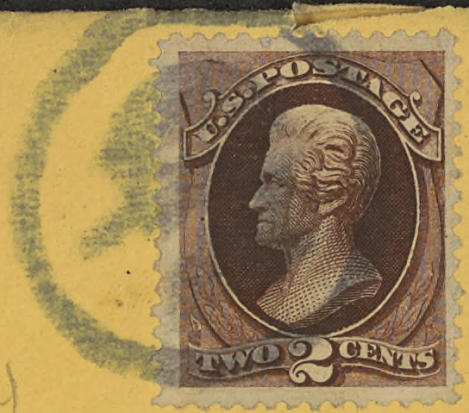

1874

George P. Davis,

City.

Bloomington, Illinois,
Oct. 21st 1874.

Dear Sir; — At a meeting of the Executive Committee of the Gothic Arch Elevated R.R. Co. it was concluded that it was important for the interests of the parties concerned, that 500 copies of the communication of Mr. Morgan to the American Society of Civil Engineers should be printed with the necessary engravings. We also think that Mr. Morgan should personally go to New York to be present at the various weekly meetings of that Society, and to communicate with its Committee before the 1st of Dec., when their final report will be made to the society. The whole expense of such printing and visit will amount to an equitable proportion of $50. per share, payable, 1/2 immediately, and the balance on the 1st day of Dec. next. Your committee are of the opinion that this expenditure is one of the highest moment to the interests of all parties concerned, and we earnestly recommend its payment by the shareholders as a means of insuring the success of our enterprise. It is very important that you should reply immediately, and you will please enclose your first remittance to R. P. Morgan Jr.

Executive Committee.

George P. Davis Esq. (One share)

500 copies (no letter)

RAPID TRANSIT.

"THE BEST MEANS OF RAPID TRANSIT FOR PASSENGERS IN AND ABOUT THE CITY OF NEW YORK."

A COMMUNICATION BY

RICHARD P. MORGAN, JR., C.E.,

TO

MESSRS. O. CHANUTE, M. N. FORNEY, CHARLES K. GRAHAM, FRANCIS COLLINGWOOD, ASHBEL WELCH AND GEN. J. G. BARNARD,

SPECIAL COMMITTEE

OF THE

"American Society of Civil Engineers."

NEW YORK:
JOHN F. TROW & SON, PRINTERS,
205-213 EAST TWELFTH STREET.
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1874.

AMERICAN SOCIETY OF CIVIL ENGINEERS,
63 WILLIAM STREET, NEW YORK.

September 15th, 1874.

SIR:—At the regular meeting held September 3d, 1874, it was—

"RESOLVED, that a Committee of five members of this Society "be appointed by the President, to investigate the necessary con- "ditions of success, and to recommend plans for—"

"*First:* The best means of rapid transit for passengers, and"

"*Second:* The best and cheapest methods of delivering, stor- "ing and distributing goods and freight—"

"in and about the city of New York; with instructions to ex- "amine plans, and to receive suggestions such as parties interest- "ed in the matter may choose to offer, and to report on or before "the first day of December, 1874."

"Messrs. O. CHANUTE, M. N. FORNEY, ASHBEL WELCH, CHARLES K. GRAHAM, GENL. J. G. BARNARD, and FRANCIS COLLINGWOOD were appointed such Committee."

You will confer a favor upon the Committee and the Society by furnishing whatever contribution or suggestions you may deem of value on the above subjects, or by calling attention to the sources of such information. Due credit will be given for all aid rendered to the Committee.

In referring to plans proposed to accomplish these objects, it is particularly desired to ascertain accurately—

1st. The route and location proposed, and the reasons thereof.

2d. The character of structure proposed in various parts of the city.

3d. A close estimate of the cost in detail.

It is greatly preferred that all communications shall be in writing.

Please address,

G. LEVERICH,
Secretary.

To

RICHARD P. MORGAN JR., C. E.,
Bloomington, Illinois.

COMMUNICATION.

MESSRS. O. CHANUTE, M. N. Forney, Ashbel Welch, Charles K. Graham, Gen. J. G. Barnard, and Francis Collingwood, Committee of the American Society of Civil Engineers:

GENTLEMEN: I have the honor to acknowledge the receipt of your circular, dated September 15th ult., in which you request suggestions and plans for the best means of Rapid Transit for passengers, and also the best and cheapest methods of delivering, storing, and distributing goods and freight in the city of New York.

I am gratified to learn that a subject of so much interest to the inhabitants of New York, and other large cities, is about to receive the examination of a society like that which you represent, made up of individuals whose personal and professional character will be likely to command, for the conclusions it may reach, the confidence of the public at large, as well as that of other members of the profession.

The great object to be attained clearly seems to be the rapid transit of *persons* between different parts of the city, rather than the carriage and delivery of merchandise in it. Already all parts of the city, by reason of its peculiar geography, enjoy excellent facilities for the receipt and delivery of property. The width of the Island at no point exceeds about two miles, and it is surrounded by navigable waters,

so that all supplies or property coming in, as well as merchandise going out, easily pass between the water and place of destination. Any resident of New York will, upon a little reflection, perceive what a vast proportion, in both weight and bulk, of all the property coming to, and going from it, are moved by water. This includes, not only all the foreign and coastwise commerce, but also all the railroad transportation, except that which passes over two lines:—the Hudson River and Harlem railroads. Nature has already provided the means of cheap and rapid transit of property as it does not exist in any other of the great cities of the world; but the very peculiarities which give this great advantage only increase the difficulty as to the transit of *persons*, inasmuch as the long and narrow island compels the latter to move lengthwise of its surface over great and rapidly increasing distances, between those parts of it occupied for business and those for residences. While the plan hereinafter to be described, it is believed, could be made as useful in the transportation of property as any railroad not upon the surface of the ground, still that does not seem to be the problem to be solved, nor is it the use for which the proposed road is mainly intended. However merchandise may come to, or go from, New York, it must be taken to and from the warehouse where it is stored, and the station where it is received in course of transportation, by vehicles through the streets. As no means of public transportation can be devised which will receive and deliver goods at the warehouses of each individual dealer, the necessity for drayage must always exist; and within the moderate distances,

as in New York, any attainable diminution is comparatively unimportant. The foregoing considerations have induced the omission, in this discussion, of plans for receiving, delivering, and distributing goods except as thus briefly suggested; and have confined my attention mainly, for several years past, to devising the best means for the rapid transit of persons in New York and other large cities.

It may be assumed, without discussion before such a body as you represent, that the only feasible method yet devised for the quick carriage of passengers in cities, is by a railway on which the motive power used shall be the locomotive engine—both road and engine to be modified to suit the special circumstances of the service required. Such a road cannot be safely worked upon the level of the streets; and it follows, therefore, that it must be constructed and operated in one of three methods:

1st. Below the level of the streets, by tunnels or their equivalents.

2d. Upon a new avenue, to be opened for the road itself through existing blocks, and so elevated as not to interfere with streets it may intersect; or,

3d. By using the lines of present streets so as not to interfere with their ordinary occupation.

The construction of any underground road, especially in the city of New York, must be so expensive as to render the probability of profit to the stockholders, to say the least, extremely doubtful.

In the lower part of that city such works must be constructed in loose sand, where the support of existing heavy buildings will be very difficult and hazardous; and in the upper part they must be ex-

cavated in solid rock, contorted in various directions, and full of seams and fissures. No tunnel, properly so called, can be built in it except at a depth so great below the surface, to secure a natural roof, that access to it becomes nearly impracticable, and light and ventilation, by natural means, impossible. It would probably be found necessary to take up the whole, or a large part, of the surface of any street during the time required to excavate the road and to change the sewers, and the gas and water mains and all their connections, and to roof over the street again by some means, so as to leave beneath room for the passage of trains. To do this would, during that time, nearly or quite destroy the usefulness of the street for all ordinary purposes. How much time such a work would require it is difficult to estimate, but that it would be very considerable will be obvious to your Committee. The objection to any plan of underground road, arising from defective ventilation, is very serious, and if locomotives be used as a motive power, that difficulty will be greatly increased, by the vast quantities of deleterious gases generated by the combustion of the fuel employed, whatever that may be, and which, to a serious degree, will incommode, and even endanger, passengers. The real extent of this objection is shown in the report of James P. Kirkwood, C.E., on the London Underground Railway, made to the Senate Special Commission of the State of New York, November 10th, 1866.

With reference to the cost of such a road, I desire to call the attention of the Committee to the official report of the Board of Trade of Great

Britain, presented to Parliament in 1871, being the only official statement which has come under my notice. In that report the length of the London Underground Railway, then completed and worked, is stated to be seventeen miles, and the total capital represented by stock, loans, and debentures, is given as £12,575,264 sterling. This gives a cost of about $3,700,000 per mile. The circumstances for the construction of such a road in London are much more favorable than they are in New York,—the natural obstacles are not so great, while all the material, labor, and money required for such construction cost less. As no accurate estimate of the cost of such a road in New York can be made, a comparative one becomes very suggestive, and probably conclusive. The plan of roads to be constructed upon independent avenues, to be opened through the blocks, is one which has been recommended by such respectable authority, and possesses such intrinsic merits, as entitle it to careful and candid consideration. The fact that it does not interfere with the present streets, except where it crosses them, is one of its most striking features, and is an advantage really great, but perhaps unduly exaggerated. Giving this plan all credit in this respect, still objections have been overlooked, or not sufficiently considered. To build such a road, the existing blocks must be cut in two, and the property thus taken lost for business uses. It should be borne in mind that the present streets are sufficient to accommodate the wants of the property for business purposes, and therefore the new avenue proposed sacrifices just so much land

as it occupies out of an area already limited, and which is valuable because it is limited. Further in this connection, it should be considered that to accommodate reasonably well the present needs of the residents of New York, more than one such avenue would be required; and in an early future, unless the city shall be strangled in its growth by lack of suitable means of transit, many avenues will be needed, and therefore by this plan a very material portion of the whole area of the city would be needlessly sacrificed. The great expense of the right of way, and that of constructing the road itself, whatever particular structure may be adopted, whether viaduct or depressed, or other form, can be easily seen, but not readily estimated with any degree of accuracy. When, as in parts of New York, land, irrespective of buildings, is worth millions of dollars an acre, the cost of the right of way of such a road would alone seem to render it impracticable. The cost of the structure, if it should be a viaduct of masonry, or an iron structure elevated as it must be to pass over all the cross streets, would be very great. Add together these sums, and it seems certain that its cost, without regard to loss of area to the city, and length of time occupied in its construction, would be so enormous as to render its profitable working a simple impossibility. It should not be forgotten that this plan, no more than the underground, presents a possibility of prompt relief. Several years must be consumed in the completion of either.

The Senate Special Commission, in their report to the Senate of New York, upon "the best means for the transportation of passengers in the city of New

York," say, "That a system of railways running wholly through blocks would involve an expense for the right of way, and resulting damages, which would render it impracticable to convey passengers for long distances, at rates of fare as low as the necessities of the case require, and would, moreover, involve too great delay in the acquisition of the right of way required."

This brief summary of two systems of roads is presented as conclusions which seem to have been reached after a protracted and full discussion, and experiences of their merits, since the Report of the Senate Special Commission, January, 1867, and are deductions which I have endeavored to make with as much accuracy as possible, when so briefly stated.

If these views are correct, we must resort to the plans for some elevated road, over and on the line of existing streets.

One great advantage is offered by these plans: they propose to utilize more fully the land already open for public transit, and thus have the merit of not interfering with existing property rights, nor reducing the area applicable to private business purposes, nor interfering materially with the ordinary uses of the streets. The present streets are proposed to be made more useful for the very purposes for which they already exist. These plans also have the merit of economy as to money, time, and space. They offer little obstruction while in process of erection; and as the parts will be prepared and fitted to each other before they are brought to their places, the structure can be very quickly put up, and during that work will occupy no more of the

street than is now used by the erection of new buildings. It is also evident that the cost of such structures can be accurately estimated before the work is begun—a valuable feature in marked contrast with the systems before mentioned. The various parts of a suitable structure are also capable of easy computation as to requisite strength, and are in familiar use in the railroad systems of the world for analogous purposes.

A railroad constructed over the centre of the carriage-way of streets, at suitable height, has the advantages of offering the least obstruction to their ordinary use, and of interfering in the least degree, if the structure is suitably open, with the light and ventilation of adjacent buildings. The space thus proposed to be occupied is now vacant, and the least useful of any part of the area of the street. It furnishes light and air, and nothing else, and this it would continue to do almost as perfectly were the road constructed. The actual surface of the street occupied will consist solely of the bases of the frames which sustain the structure; and as these are proposed to rest upon the sidewalk, near the curb-stone—the portion of the surface of the street least valuable for general use—the obstruction is thereby reduced to a minimum, and need not exceed one-thousandth part of the surface area of the street.

Before proceeding to state more in detail the plan which I propose, some considerations as to other plans may be suggested. Of the various elevated plans recommended in the report of the Senate Special Commission, the one appearing to them "to have been most carefully prepared, the most

free from engineering difficulties, involving the question of safety, and the least objectionable as to the application of the motive power," was that designed by Mr. C. T. Harvey, C. E. This plan is sufficiently designated as the one now so well known as the Greenwich Street Elevated Railroad, as originally constructed, supported by a single line of posts near the edge of the sidewalk, on which the cars were to be propelled by means of a series of endless wire ropes, moved by stationary engines, placed at intervals of about fifteen hundred feet. This method of propulsion proved impracticable, and after it had been provided and attempted to be used, the company who erected the road were compelled to abandon it and substitute therefor locomotive engines, for which their road was ill adapted; and yet, the structure employing a motive power not originally intended, has met, it is said, with a measurable degree of success. Among all the roads proposed to secure rapid transit in New York, this is the only one which has, even in part, been brought into practical use, and it has demonstrated three things:—1st, That the occupation of the sidewalk near the curbstone by the posts supporting the road, which are much more frequent than in the plan I propose, injures the public inappreciably; 2d, that the passage of locomotive engines and cars partly over the sidewalks, subjects the occupants of adjacent buildings to little annoyance; 3d, that the passage of such engines has no effect in frightening animals on the street. Whatever the engineering defects of the structure of that road may be, it is fairly entitled to the

credit of being the pioneer of rapid transit in New York.

The only other plan which has been suggested for the construction of an elevated road in the streets that seems to invite consideration, proposes to set up, at intervals of about sixteen feet, posts in the middle of the roadway to support tracks for the passage of engines and cars.

Heretofore it has always been assumed that any plan for rapid transit must leave the carriage-way of the street entirely unobstructed, and engineers have therefore directed their attention to devising methods which would secure the end desired without infringing upon this indispensable requisite. The structure thus proposed is the first one ever suggested which designs to use any portion of the carriage-way for the support of a railroad. It is nothing more than a simple trestle bridge, made of iron it is true, which has been known since bridges were first used for the crossing of small streams. If such a primitive plan can be tolerated in the numerous avenues that must be brought into this service to properly accommodate the public, the labor of the last twelve or fifteen years, which was devoted to this subject, was quite useless, and the delay and inconvenience which the people of New York have suffered were unnecessary. Such a road would be cheaper, equally efficient and more quickly constructed than any other road not on the surface. It is extraordinary to say the least that a road so built should not, long ago, have been proposed, if it is to be permitted, and therefore it must have been kept in the background for sound and obvious reasons. Nothing but the great and increasing

necessity of the people of New York for means of rapid transit, and the want of success in the adoption of other plans proposed and generally discussed, could probably have induced the suggestion of such a plan,—one which subjects the public to such serious inconveniences, and sets aside all considerations except those of mere utility in construction. The objections seem to be insurmountable. Suppose the road to be constructed as has been suggested along Third Avenue, over the present surface railroad tracks. The width of the supports of a double track railroad so elevated must be more than twenty feet. The carriage-way of that avenue is sixty feet, and there would be left therefore, on either side of the trestle-work, less than twenty feet in width. The middle of the carriage-way of any street is always the part most useful, because near the curb-stone teams necessarily stop to load and unload, and obstruct, in that part of the street, the passage of vehicles, and two teams going in opposite directions, with but twenty feet space, could not pass each other whilst a team was loading or unloading at the sidewalk. If the posts or bents to support the elevated road are set up at intervals of sixteen feet, as proposed, teams can cross the track only substantially at right angles, and if the present surface road is to continue in use, such crossing, hemmed in by posts which they must pass, becomes difficult for fear of collision with the street-cars. At present passing teams use that part of the street occupied by the railroad tracks, and are able, without difficulty, to turn off when the approach of a car makes it necessary; but if those surface tracks are to be

run between rows of posts, set up on both sides sixteen feet apart, it will be difficult for any, and impossible for many, of the vehicles to get on or off that part of the street, except to make a direct and hazardous crossing. In effect, it is to give up one-third or more of the carriage-way of the street entirely to railroad uses, and destroy it for all purposes of ordinary traffic. The part thus surrendered is that, the use of which for ordinary purposes most facilitates the use of the other parts—the sides and sidewalks—for the purposes which they alone can effect. In narrower streets than the avenues, these objections become still greater,—unless, indeed, the street is so narrow as to be spanned by the bents of the trestle-work, in which case the proposed structure becomes one supported over the carriage-way by posts resting on the sidewalks, and frees itself from what must be regarded as vital objections.

Keeping in view what has already been suggested of the importance of utilizing the space over the central portion of the roadway in the existing streets,—if the same can be done without serious interference with their present use, or injury to the adjacent property, by a structure not too costly,—it would seem that a plan combining all these advantages recommends itself to public favor and adoption. To this end, I have devised and patented a plan for sustaining a double-track railway over the centre of the street at such elevation as not to interfere with its ordinary use, and occupying, at the surface by the supports, a space least in amount and value. It is evident that the edge of the sidewalk near the curb-

stone is the least useful for general purposes. Upon this space I propose to erect iron ribs opposite each other, and meeting over the center of the street in the form of a Gothic Arch, springing from a tangent line perpendicular to the sidewalk at the walk, or at any suitable height above it, depending upon the width of the street or changes in the grade of its surface. Between these outer ribs, a flat elliptical rib is placed at an elevation above the street so as not to interfere with its use, and firmly secured to the outer ribs by such connections as will appear in the plans herewith submitted, and so as to form a competent transverse frame, such frames to be set up at suitable intervals,—say about seventy-five feet, as an economical distance. The office of these frames is the same as that of the piers of an ordinary bridge, to sustain a series of longitudinal trusses, which latter carry a double-track railway above and over the middle of the street. The cars move on the tracks above the elliptical and under the outer ribs before described. Carefully constructed foundations of masonry are brought up from any needed depth to the sidewalk, and there, capped with an iron bed-plate and sleeve, to receive and unite with the exterior ribs. From the middle of the lower elliptical ribs to the apex of the outer ribs, a longitudinal iron truss extends from frame to frame, and, aided by similar trusses on each side, supports the tracks. Between those outer trusses, and passing across the bottom cord of the middle one, are laid, at suitable intervals, the floor-beams, also of iron, which directly supports the tracks. These floor-beams are to be connected diagonally, so that they shall act as a

horizontal truss to prevent any lateral swaying of the structure, the whole to be left open so as to prevent the accumulation of snow or other obstructions, and to avoid interference with the light and ventilation of the streets as far as possible. The outer and inner ribs are firmly united by horizontal, vertical, and diagonal connections, so arranged that the resultants of forces acting upon them, derived from the weight of the railroad and rolling stock, are uniformly resisted. The curved line of the outer ribs enforces their yielding in one direction only—outwardly—which is readily and effectually met by the interior connections. The railroad is thus suspended, and constitutes a load on the exterior of the arches equally distributed. The outer ribs are not bearing-posts simply, unaided by the principles referred to, except that portion of them below the intersection of the interior rib with them,—about ten feet in height above the foundations. For this portion of those ribs the necessary additional material is introduced to overcome the loss of sustaining power, compared with that of a straight post, occasioned by the slight deflection of the curved rib. In all other parts of the frames, the greatest economy in the use of material is attained. Access to the cars is proposed to be given by covered ways and platforms, constructed of iron and glass, leading from stations provided at suitable intervals, and in which passengers can wait for the arrival of cars. These waiting-rooms should be in the buildings on both sides of the streets, one for up and one for down cars, so as to make it unnecessary for any passenger ever to cross, or even to go upon the tracks. If the

platforms are placed opposite the cross streets, as it is desirable they should be, the light of buildings on the street will be unaffected. The approaches to the waiting-rooms will be by staircases in the buildings in which the waiting-rooms are situated. The floor of the cars, the top chord of the side trusses, and the floor of the platform leading from the station, should be upon the sand level, so as to offer no obstruction in obtaining access to the cars. The durability of the material employed, and the facility with which repairs can be made by reason of the ready access to every part, and its being practically unaffected by rain, frost, or snow, and its greater freedom by reason of its material, and its location in the middle of the street, from danger of injury by the burning of adjacent buildings, combine to secure the perfection of the work, and thus insure the safety and regularity of trains passing over it. It is easily seen that such a road as this, suitably constructed, will approach more nearly to a perfect railroad than any road yet built ever has; it will have no switches on its line of travel to be misplaced; very slight irregularity of surface or of alignment in its tracks; and consequently the dangers of existing railroad travel already less than those of any other means of communication, and which are mainly due to those two causes, will be reduced to a minimum. To some persons, the fact that the road is at all points considerably elevated above the ground may suggest a fear of danger in case of accident by derailment. What is stated above shows the small risk that such an accident can occur; but even if it should, the arrange-

ment of the structure is such that the effect will be no greater than to a train running off a track on the level of the earth. The iron framework supporting the track will, in such a case, uphold the cars, and the side trusses will act as a real and substantial railing, so that in no case can the cars be precipitated to the ground. These considerations also demonstrate the increased capacity of such a road over one of ordinary construction. The more nearly perfect the road, the greater the certainty with which trains can be worked upon it, and the more frequently they may safely be passed over it. It is difficult to see why trains may not follow each other at no greater intervals than may be required to check the speed of one, so as to insure the safety of that immediately preceding it. These intervals, with the light trains proposed to be employed in passenger traffic, and their consequent small momentum, will be so short that no more than a single minute of time need be interposed on either track between the passage of trains, thus insuring a degree of efficiency such as has not been in practice attained on any road yet constructed. This frequency of trains is an indispensable element of success in whatever plan of road may be adopted, and without it neither the wants of the inhabitants of New York can be met, nor the confidence of capitalists to construct the road be secured.

For the purpose of carrying *persons* up and down Manhattan Island, it is not necessary to use the immense locomotives and trains so familiar to us all. Light and perfectly enclosed engines, with suitable cars, can be run on a properly constructed road

with great frequency, giving large capacity for the purpose desired; nor will it be contended that such engines and trains passing on several lines, at brief intervals on each route, would fail to serve the public convenience better, and with greater safety than the ordinary engines and trains in general use in the United States,—trains heavy in themselves, and designed to move great accumulated weights. The momentum of such trains renders frequent stops very difficult,—hence the public convenience in this regard cannot be well served by their use. A locomotive weighing six tons, with a suitable train of cars, is competent to move one hundred and fifty passengers on the proposed road with less noise than is made by an empty omnibus, and this too at any desirable speed, and with any grades that the larger engines and corresponding heavy trains can work upon successfully. Reduce the problem to its simple and true form,—the transportation of *persons*,—and it may be doubted if any one of extended experience in such matters will advocate for New York the cumbersome and heavy engines and trains employed on our standard railroads, where the stops are infrequent and the uses so different. The access to cars on this road would be quite as convenient as to those of any other. Whatever road is built must be either above or below the present surface of the ground. If upon a new avenue, still it must pass over the cross streets at such a height as not to obstruct their traffic, or, in other words, must be elevated as the road now proposed. If the road should be built below the surface, the depth of the excavation must be at least as great as the height required

for an elevated road, and the ascent and descent in either case will not be lessened.

I have endeavored to present the foregoing suggestions in a form as much condensed as is consistent with clearness, and have omitted many statements which would be proper in addressing the public at large, instead of a body of gentlemen whose professional experience renders such amplification unnecessary.

As to location, if but one road is to be constructed, the line of Broadway from the Battery to 9th Avenue, with a branch from near Union Square to Third or Second Avenues, and thence substantially following the lines of those avenues, is clearly indicated as a natural location; therefore the line which shall most nearly conform to it, will more fully accommodate the citizens of New York than any other single route. When more roads are needed they may be constructed along other avenues, connecting with the lower parts of the city on such streets as may be most convenient and feasible, and also a road built around the Island near its water line.

The character of the structures proposed in various parts of the city I think should be substantially that already described. It may be modified where the width of the street requires the tangent line of the outer rib to be produced upward to give headroom for the passage of cars through the frames, and this modification may be made until the width of the street is so reduced that an adequate girder beam becomes more economical than the frames. The same modification of the outer rib can also be employed to diminish the grades of the railroad

from those existing in the surface of the streets. The long experience of inconvenience and danger to the public, furnished by the use of steam on railroads on Fourth Avenue, and the great work now in progress of sinking the tracks of those roads solely to obviate that difficulty, present conclusive evidence that no railroad adapted to rapid transit can be properly placed upon the surface of the street anywhere on Manhattan Island.

I herewith submit, as requested, and offer myself to criticism for excessive employment of material, estimates of the cost of constructing such a road as is proposed. One for a road especially adapted to quick transit of passengers, and the other with a structure made competent to the use of ordinary locomotives and the trains in general use throughout the country. The aggregate cost of that for passengers only, and the employment of engines weighing six tons, will not exceed $520,000 per mile. The total cost of a road for the use of the ordinary heavy engines and trains amounts to $841,104 per mile, which is presented in detail, with a general plan, and appended hereto. The latter estimate shows a largely increased cost over the one for passengers only, and both present striking contrasts in cost compared with the underground plan, or an elevated road on an independent avenue.

It is clearly unnecessary that I should present to you a complete scientific discussion of this plan for an elevated railroad, which employs mainly old and well approved structures under new combinations. All of the longitudinal portion of the struc-

ture proposed is in common employment under the highest velocities reached by passenger trains at points of greatest elevation, and required safety—namely, the crossing of streams and mountain gorges on all the railroads now constructed everywhere in the world. If the transverse frame which upholds it is made of iron or steel, as durable and capable as a granite pier, we have then completed a double-track railroad of great perfection, and free from the slightest taint of experiment. Is there a civil engineer of character, culture, and experience in his profession who will say it cannot be done? I desire, in conclusion, to call your attention briefly to some of the practical, economic, and esthetic reasons which should govern conclusions as to the form to be adopted for sustaining a double track railroad in the vacant and unoccupied space over the center of the streets.

One-half of the weight of trains passing each other, and the weight of the longitudinal trusses and tracks, is received at the apex of the outer ribs, and carried in equal parts down the line of those ribs to the foundations. The other half of the weight of those trains is simultaneously received by the outer ribs in equal parts, one-fourth each of the whole load, near the intersections of the upper horizontal girder-beam with those ribs, and thence uniting with the load from the apex, the aggregate weight is carried to, and received vertically, by the foundations, upon which the whole structure stands square and firm. The location of the tracks, the upper and lower horizontal girder-beams, and the elliptical arch, are, by the aid of the center, quarter,

and detail connections, designed to place the load uniformly on the frame. When a train moves upon but one of the tracks, only a fourth of its weight is transmitted through one rib, and three-fourths through the other. The base is constant, therefore the equilibrium of the transverse frames is not only very stable when the tracks supported by them are unoccupied, but at all times, either when trains are passing each other, or when a single train is moving over the road, and the necessary strength of the arches and interior connections, for the greatest service required, will be found quite equal to maintaining their form under a partial load.

The application of three longitudinal trusses,—a deep center truss supported from the apex of the arch, with competent shallower side-trusses, all secured to the transverse frame which supports them, presents many reasons favorable to their employment, and that method of combination in forming the whole structure. They occupy about 20 per cent less of the street area than would be the case if the tracks were carried on a deep truss on each side, between which the cars must pass, and avoid presenting to the eye of passengers a continuous network of iron, and the difficulty and danger of access through those trusses. The top chord of the low side-trusses being below the car windows, would give passengers a pleasant view of the sidewalks and other objects unobstructed, except at the ribs, about 75 feet apart, and at all times they would ride in full light and open air. The freedom of access to the cars thus attained,—the top chord of the side-trusses, the platform of the depots, and the floor of

the cars, being on the same level,—is a great consideration. Convenience, pleasure, and economy of space, are not only better served, but the cost of the structure is materially diminished, and mechanically improved, by the necessary subdivision of the floor-beams which uphold the tracks, involved in the employment of three trusses. The center truss, it is true, presents panels too short for the best proportion and greatest economy, in consequence of their conformity to the panels of the side-trusses, but these disadvantages are greatly overcome by the compactness, economy, and symmetry of the structure as a whole.

The fact being assumed that rapid transit in large cities can be effected in the best manner by means of elevated railways over the centre of the streets or avenues, it is evidently of the utmost importance that the mode of their construction should be in the best practical form attainable, and also of the material best adapted to the purpose.

There are certain conditions which are inseparable from a satisfactory accomplishment of the object, which, unless they involve greatly increased cost, must be rigidly adhered to. The great thoroughfares over which the structure will be raised, must not be obstructed. Light and air must be excluded from adjacent buildings in the least possible degree. For durability and safety, the material must be iron or steel, employed as science and experience indicate, while elegance of form can by no means be neglected. Several plans have been recommended, but it is evident that the most approved truss used for bridges, supported at intervals of about seventy-five feet, by

suitable transverse frames extending from curb to curb, admits in the best possible manner of a full compliance with the conditions required.

It may be suggested that strength and economy would be met most effectually by avoiding curvature in the construction of the transverse frames, and by the adoption for a general plan of inclined straight posts to sustain the superstructure. This form of construction, for the great object under discussion will hardly find advocates, even if it were the least costly, which cannot be successfully maintained.

In the early stages of civilization the rudest kind of architecture prevailed. Straight timber and square blocks of stone were naturally resorted to as the simplest method of meeting the wants of the community; but as people became wealthy the skill of the architect was patronized, and beauty of form combined with strength, constituted the object of their ambition. In no instance does history afford so remarkable an example of success in this particular, nor is there at the present time any structures so incomparably elegant, while possessing the maximum of stability, as in the ancient Gothic architecture of Northern Europe. Lightness, grandeur, and durability exhibit irresistible arguments in favor of the great principles of form from which these buildings originated. They remain as monuments of the genius, knowledge, and taste of their founders.

The necessary proportions of a transverse frame for an elevated railway on a street from forty to sixty feet wide, constructed in the form of a Gothic arch, very nearly correspond with those of Westminster Abbey and several other churches renowned

for their great beauty. Nothing more elegant can be devised for the purpose ; and while possessing ample strength and remarkable compactness and stability, its slight curvature does not require a greater aggregate weight of material than the angular form which the straight-line system involves. The city of New York, for which such a great destiny is universally conceded, cannot permit a permanent structure on the lines of its streets and avenues which fails to present a combination of grandeur, grace, and utility in harmony with the best architectural features of the city, and competent for the uses of its citizens.

Very respectfully submitted,

RICHARD P. MORGAN, JR.,
Civil Engineer.

Bloomington, Ill.,
October, 1874.

APPENDIX.

ESTIMATED cost of the Gothic Arch Elevated Railroad, adapted to Broadway, New York, to support a double track, of ordinary gauge, and competent to a moving load of 2,000 lbs. per lineal foot on each track,—the coefficient of safety not less than six (6)—the whole to be completed in a thoroughly workmanlike and tasteful manner.

Estimate for one span, 75 feet.

Foundations (approximate average from the Battery to Fourteenth street), excavation and filling:	
150 cubic yards, @ 40c.	$60 00
20 cubic yards masonry, @ $16.00	320 00
Iron in one transverse frame:	
Round iron, wrought, 2,000 lbs. @ 8c.	160 00
I beams and plates, 40,000 lbs. @ 8c.	3,200 00
Cast iron bed-plates, etc., 10,000 lbs. @ 6c.	600 00
Iron in longitudinal trusses, one span:	
Girders, 37,875 lbs.	
Cross-girders, 12,900 lbs.	
Underwork, 8,850 lbs. = 59,525 lbs. @ 8c.	4,762 00
Rails, etc.:	
Steel rails, plates and bolts, 7,500 lbs. @ 5c.	375 00
Medium:	
Between the steel-rails and the iron cross-girder beams, $5.00 per lineal foot	375 00
Stations and entrance-ways:	
Four per mile, two on each side, at $10,000 each, equals rate per section of 75 feet	520 00
Painting and finish:	
Three coats of paint, @ 6c.	489 60
Engineering and contingencies, 10 per cent.	1,086 16
Total for 75 feet	$11,947 76

$11,947.76 ÷ 75 = $159.$\frac{30}{100}$ per lineal foot.

$159.30 × 5280 = $841,104, total cost per mile.

Attachment of intermediate post to upper Chord. Scale 2" = one foot

Link attachment of upper chords at Arch 2" = one foot

Section and Elevation of Base 2" = one foot

Section of Base one foot

GOTHIC ARCH

ELEVATED CITY RAILWAY

RICHARD. P. MORGAN. JR

PATENTEE

Scale ½" = one ft

Elevation of Arch

Elevation of Span

Plan

Stonework Foundation

Cross section at centre of Panel